SPAWAR
Systems Center
San Diego

Selected WDM Military Interests

Steve Pappert & Bill Jacobs
SPAWAR Systems Center, San Diego (SPAWARSYSCEN)

DARPA WDM WORKSHOP
28 JUN 01

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
28 JUN 2001	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Selected WDM Military Interests	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **SPAWAR Systems Center San Diego, CA**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
DARPA/MTO Workshop held June 28-29, 2001, at the Los Angeles International Airport Marriott, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

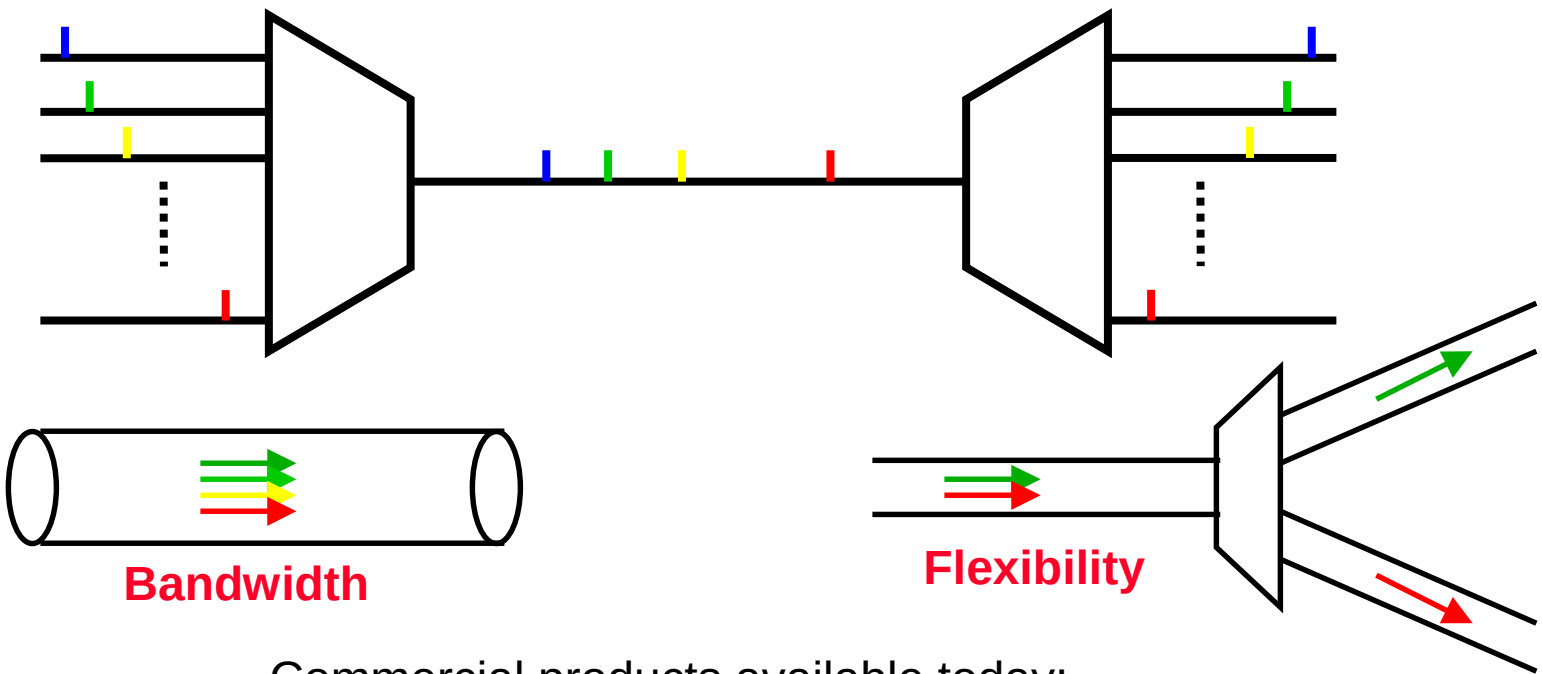
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**13**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Wavelength Division Multiplexing (WDM) Commercial Technology

SPAWAR Systems Center San Diego

WDM uses multiple wavelengths of light to increase the *bandwidth* and architectural *flexibility* of a fiber optic networking system.



Commercial products available today:

- 2 to 100+ wavelengths (DWDM/CWDM)
- > 400 Gb/s capacity

Evolution of IP Photonic Networks

Systems Center San Diego

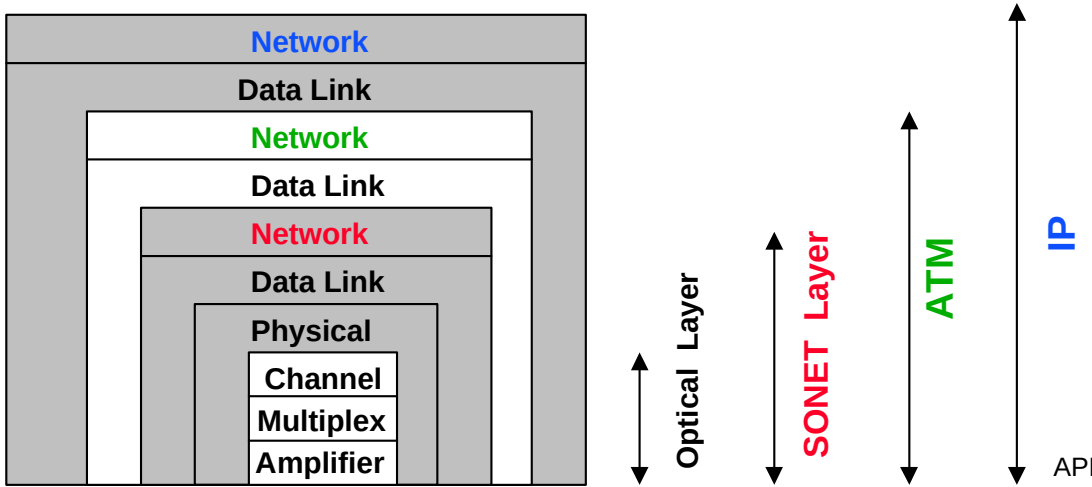
Trend towards less network management

1998	2001	2004
IP	IP w/ MPLS	LAN / MAN
ATM (QOS)	SONET	IP
SONET	WDM	10Gb Ethernet
WDM		WDM

Along with Ethernet technology, WDM technology will become prominent in Metro Area Networking (MAN) and Local Area Networking (LAN) topologies.

Military platform networking most resembles the MAN environment with high priority on Quality of Service (QoS).

Level 3 and below



WDM Technology

SPAWAR Systems Center San Diego

Commercial implementations

- mature technology for long haul ***high bandwidth*** networks (DWDM)
- recent commercial implementation in MANs and SCM access
- many system implementation competitors (Lucent, Nortel, Ciena, AT&T,..)
- many component suppliers (JDSU, Corning, Lucent, Nortel, Alcatel, Agere, …)

Research and Development

- Components
- Applications, e.g., CWDM Ethernet; optical packet switching

Narrow band laser transmitters / VCSELs	Photodiode receivers
Optical multiplexers / demultiplexer	Optical amplifiers
Fiber Bragg gratings	Add-drop filters
Narrow band optical filters	Wavelength converters
External modulators	Optical switches
MEMS devices	Integrated optical circuits

Military can leverage on commercial WDM investment

- future bandwidth requirements
- ***additional*** Navy/DOD requirements and applications

Military WDM Technology

SPAWAR Systems Center San Diego

A few areas of military WDM interest:

- **Network ruggedization**
- **Mixed signal antenna networking**

Need to differentiate required technology from ongoing ***commercial*** *activities*

- **Optical signal processing**
- **Optical domain microwave filtering**

Need to differentiate required technology from ***DARPA AOSP*** Program requirements

Need for Advanced Mixed Signal Optical Networking

SPAWAR Systems Center San Diego

Current Optical Networking Technology

High-speed digital networks

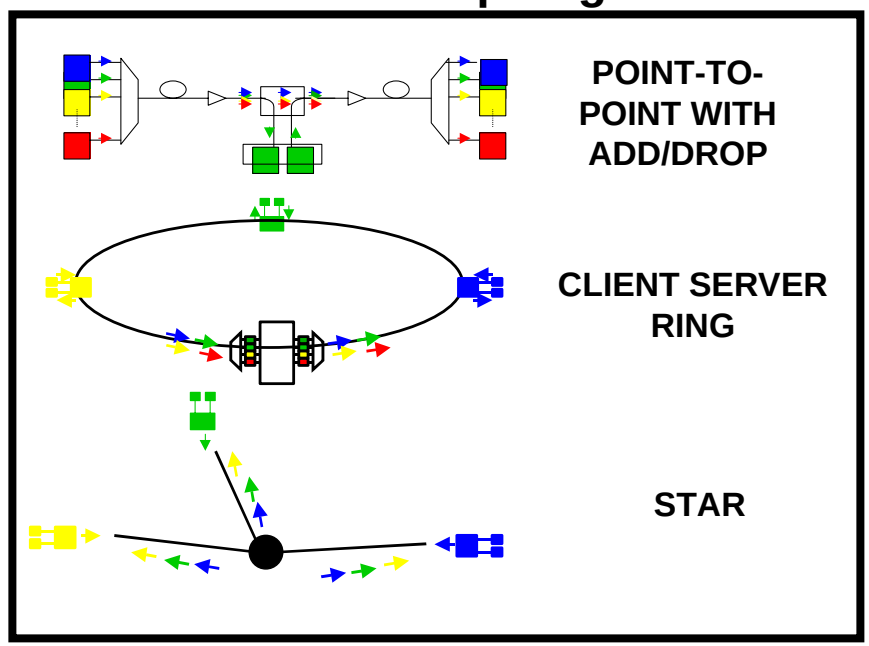
- 10 Gb ethernet
- WDM with >100 channel throughput

High-speed RF networks

- Low loss microwave fiber optic links
- High dynamic range links
- >40 GHz bandwidth available
- Sub-Carrier Multiplexing (SCM)

  [CATV, MAN]

Network Topologies



Future Military Optical Networking Vision

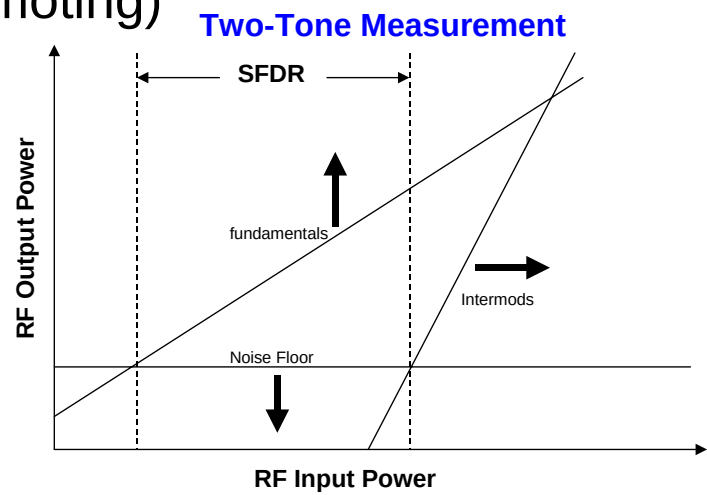
High-capacity mixed signal SCM/WDM fiber-optic networks satisfying Military Vision 2020 platform requirements.

High Bandwidth / High Fidelity / High Sensitivity Military RF Networking Issues

SPAWAR Systems Center San Diego

- SIGINT/RADAR/COMMS: >80 dB SFDR typical with close to thermal limited RF detection
- *Wideband* military requirements much more demanding than commercial applications that require either *Fidelity* at high input RF powers (CATV) OR *Sensitivity* with lower dynamic range (Wireless Remoting)

Can military RF signals share a common WDM backbone network with digital signals???

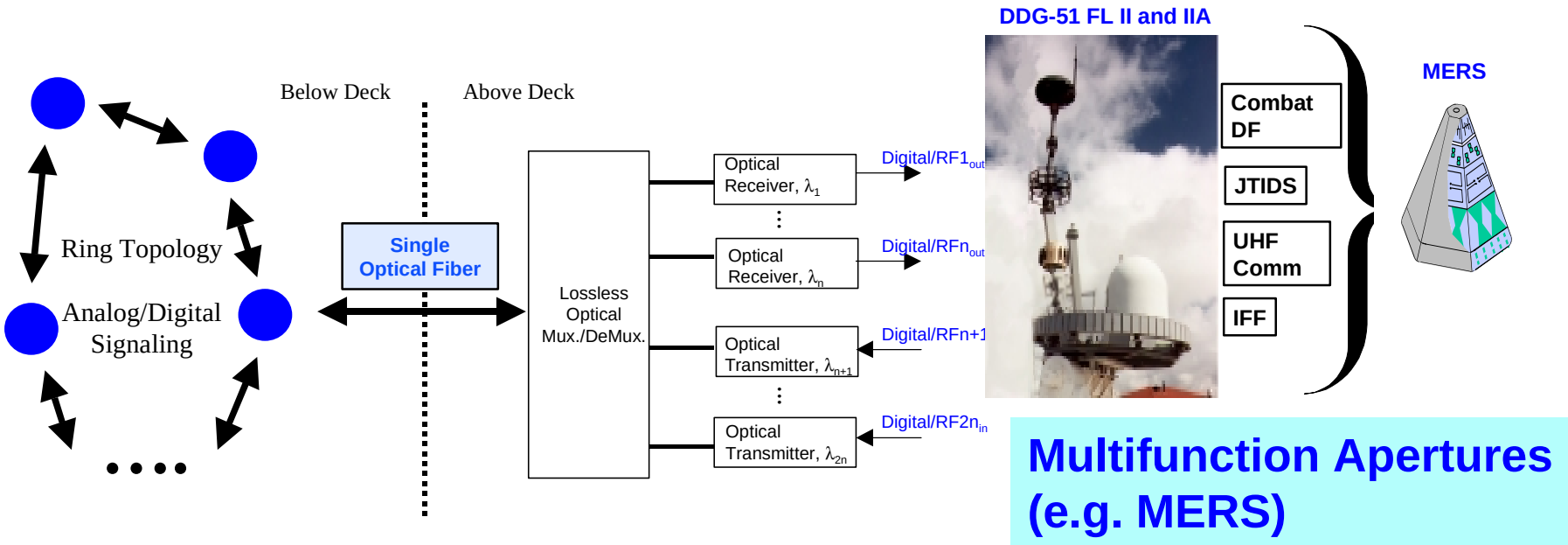


RF Network Components

- Modulators (efficiency, linearity, bandwidth)
- Lasers (DFB; FP; VCSEL) (power, efficiency; amplitude noise, linearity, bandwidth)
- Receivers (efficiency, power handling)
- Fibers (MMF; SMF) (modal, polarization, and chromatic dispersion)
- EDFAs (noise figure, optical bandwidth)
- MUX/DEMUX/ADD/DROP/COUPLERS (loss, isolation, polarization sensitivity)
- Switch Arrays (loss, isolation, polarization sensitivity)

WDM/SCM Sensor & Platform Information Networking

SPAWAR Systems Center San Diego



- **Network accommodates ANALOG and DIGITAL signaling**
- **Useful for Vision 2020 military networks and multifunction antennas**
- **Sensor and network information available in real-time on demand**
- **WDM provides increased flexibility, reduced installation & servicing time**

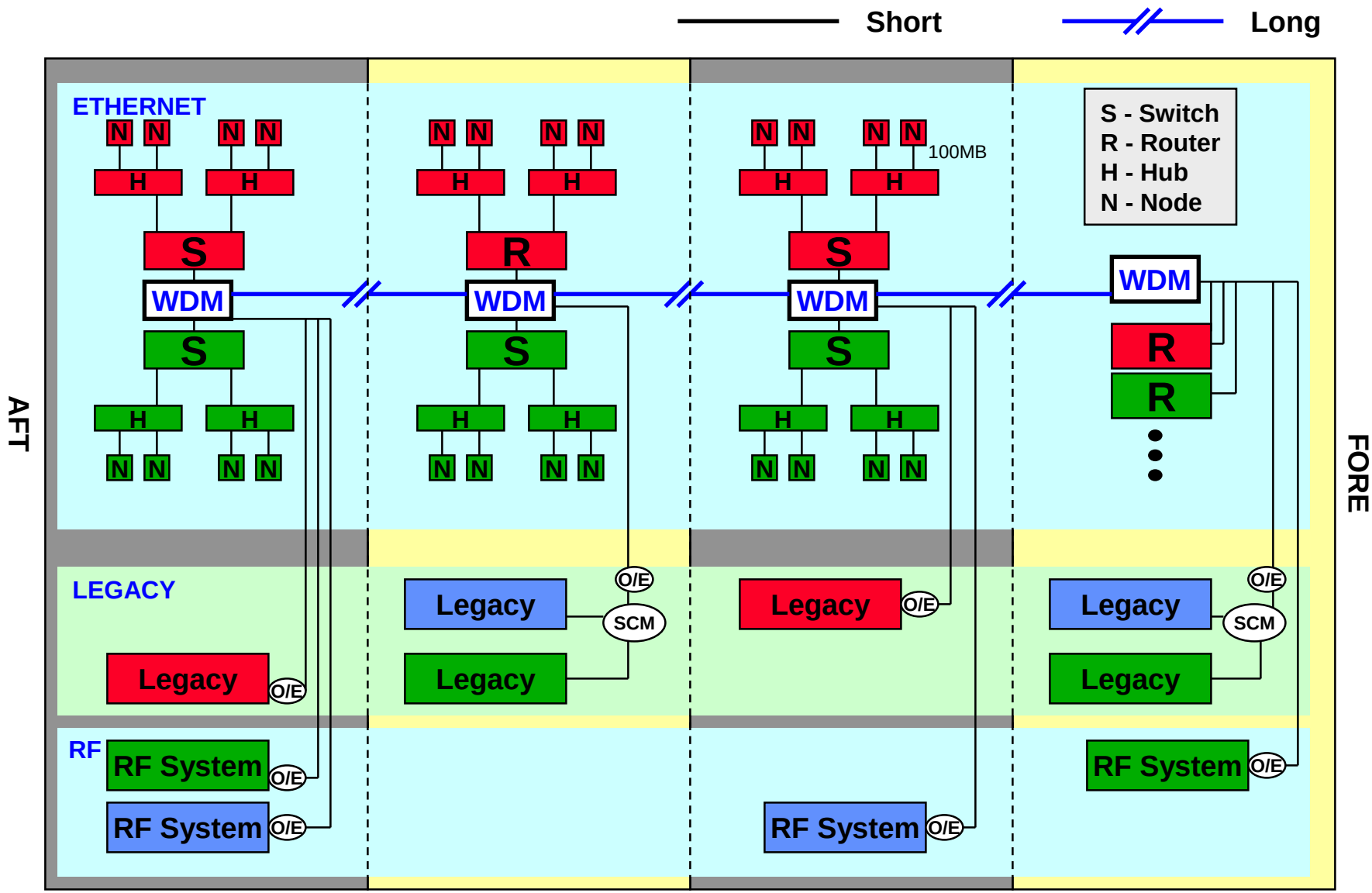
Remaining R&D Challenges:

1. Improved ***Analog WDM*** fiber optic link performance
2. ***Integration & Packaging*** of SCM/WDM link components

Future Shipboard Networking

Connections via WDM backbone

SPAWAR
Systems Center
San Diego



Microwave Photonic Signal Processing

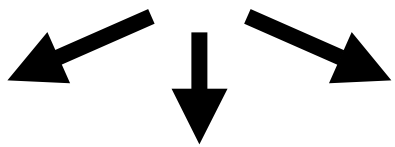
System Capabilities

SPAWAR Systems Center San Diego

- **Optical Domain RF Frequency Conversion & Filtering**
- **Optical True-Time-Delay (TTD) RF Beamforming**
- **Fiber Optic Delay Line RF Signal Processing**

Military RF System Insertion Targets

Communications, Radar, Navigation, & Electronic Warfare Systems



Airborne & Space Platforms
Army, Navy & Air Force

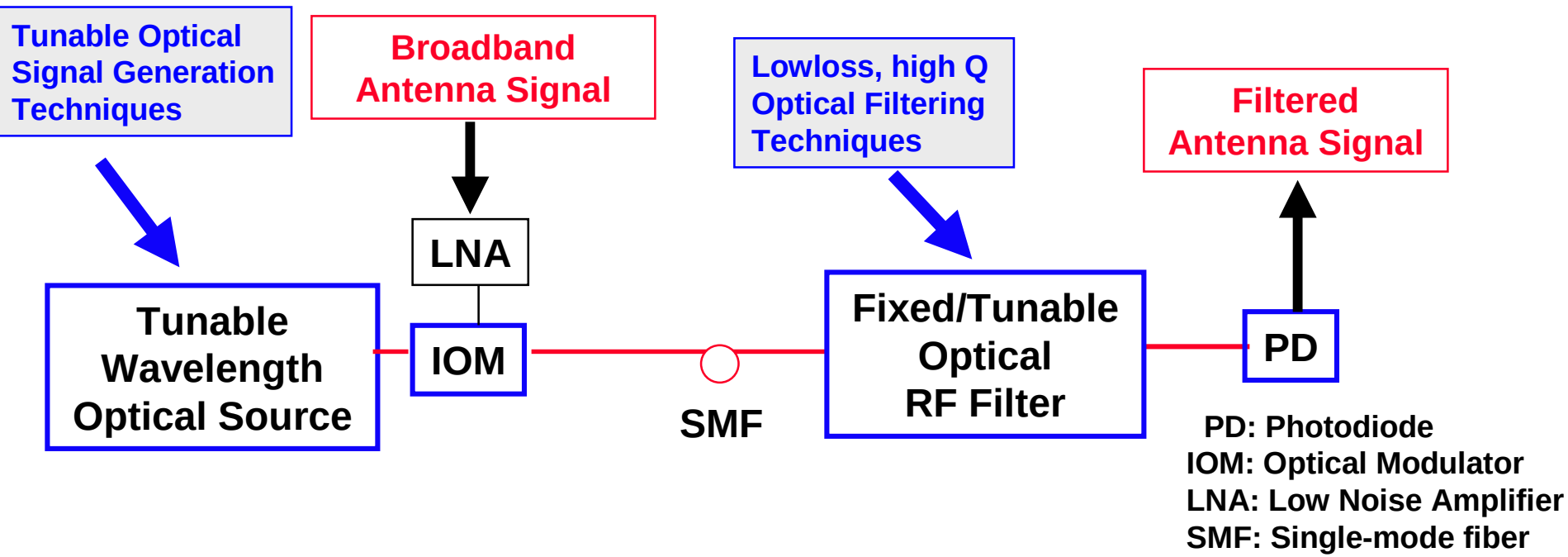
Maritime Platforms
Navy

Ground Platforms & Facilities
Army, Navy & Air Force

Microwave Photonic Signal Processing Example

SPAWAR Systems Center San Diego

Optical Domain Microwave Filtering
(All Optical Superheterodyne Receiver)

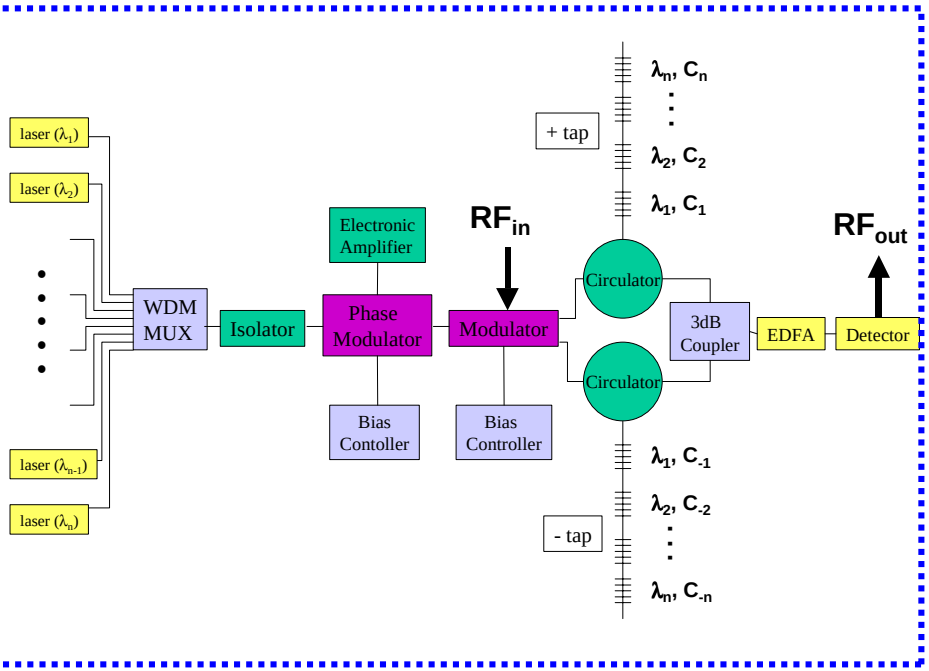


- Eliminates need for electronic mixer (reduced front-end complexity)
- Incorporates pre-selector filtering in optical domain
- Builds upon commercial DWDM telecommunications and millimeter-wave fiber-radio system technologies

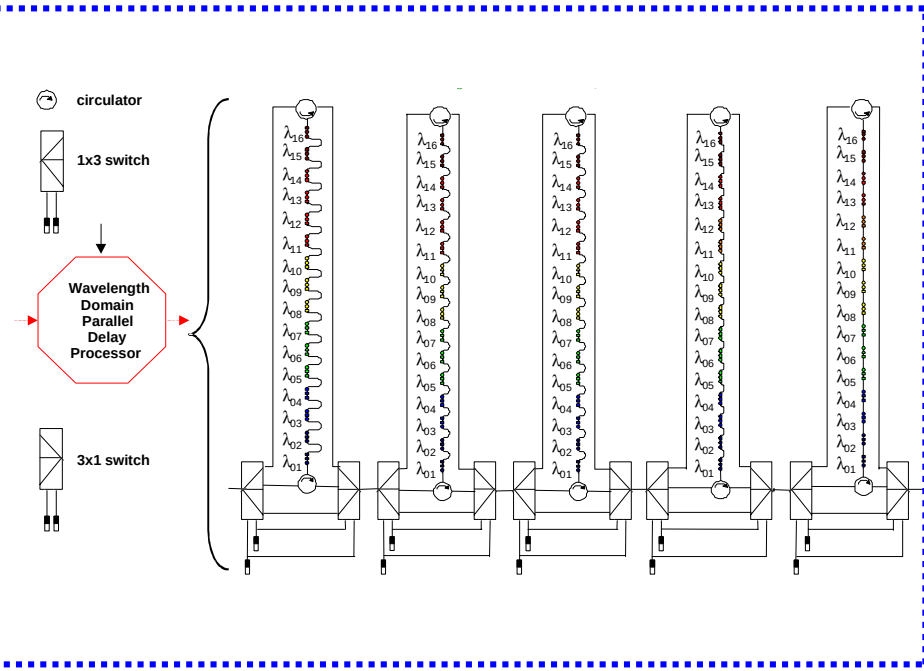
Microwave Photonic Signal Processing Example

SPAWAR Systems Center San Diego

WDM Based Signal Processors



RF PHOTONIC FRONT-END TRANSVERSAL FILTER



WIDEBAND OPTICALLY MULTIPLEXED TTD BEAMFORMING ARCHITECTURE

- **Wavelength dispersive signal processing architectures**
  - **Fast tunable lasers**
  - **Broadband optical sources**

Enabling WDM Component Technologies

SPAWAR Systems Center San Diego

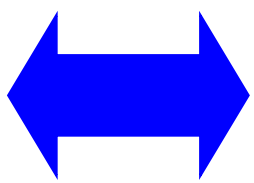
WDM-Based Building Block Examples:

- High channel isolation (>40 dBo), polarization independent passive components
- Fiber Bragg Grating (FBG) arrays
- High-speed (<1 μsec) tunable optical filters
- Optical domain tunable microwave filters
- High-performance digital/analog WDM transmitter arrays
- High power, low noise, wavelength selectable laser diodes
- High-speed tunable lasers (continuous and discrete)
- High power, spectrally equalized supercontinuum optical sources
- Optically broadband E-O modulators/switches
- Low loss WDM optical switching arrays
- Ruggedized Erbium Doped Fiber Amplifiers (EDFAs)

Proposed Program Goal: Integrated WDM Modules & Functionality

Grand Challenges

Low cost
Size, weight and power
Environmental stability



Advanced Fabrication, Integration & Packaging